FACTS AND REASONNIGS CONCERNING THE HETEROGENOUS EVOLUTION OF LIVING THINGS *

II.

A.—*Experiments in which the fluids employed were raised to a temperature of* 100° *C. for from* 10 *to* 20 *minutes before the flask was hermetically sealed.*

a. Fluids employed being filtered infusions containing organic matter in solution.

1. *Infusions either slightly alkaline or neutral.*

Experiment 1.—A flask containing filtered beef-juice *in vacuo*, which had been hermetically sealed twelve days previously, after the fluid had been boiled for 15 minutes, was opened on January 7, 1870.

The solution itself was clear, and there was no pellicle on its surface, although there was a slight flocculent deposit at the bottom of the flask. The end of the flask having been broken off and its contents shaken, the first drop which was examined with a magnifying power of about 600 diameters † showed the most unmistakeable living organisms. There were mere moving specks or monads (*a*); several active organisms made up of two minute sphericles (*b*); a few medium sized, actively moving bacteria (*c*); an actively moving spheroidal body $\frac{1}{10000}''$ in diameter (*d*); and several simple cellular bodies with a moderately thick cell wall, but apparently containing only fluid contents. These latter bodies varied in size from $\frac{1}{7500}''$ to $\frac{1}{3300}''$ in diameter. Most of them were simply ovoidal (*e*), one or two of them were seen to be more irregular in shape, either having projections (*f*), or even, as in one case, presenting projections something like cilia.

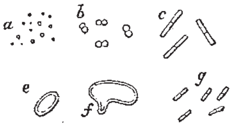

FIG. 6.—*Monads, Bacteria*, and other organisms met with in first experiment.

In the second drop of fluid examined, with the exception of a little granular matter, there were only seen several small but very active bacteria (*g*).

Experiment 2.—A flask, containing a mixed infusion (rather weak) of beef, carrot, and turnip, *in vacuo*, which had been hermetically sealed fourteen days previously, after the fluid had been boiled, was opened on December 23, 1869. The first two or three drops showed a large number of actively moving monads; a number of moving particles having an altogether irregular shape; bacteria distinct and moving, though less numerous; a number of spherical *Torula*-like cells of different sizes, containing a central dot (*a*); and a number of bodies mostly in the form of parallelopipeds with rounded angles (*b*), though some were quite irregular in shape—these containing granules of various sizes, with sometimes large and altogether irregular protoplasmic-looking masses.

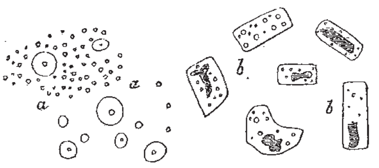

FIG. 7.—*Torulæ* and other organisms met with in second experiment.

Experiment 3.—A flask containing a weak decoction of beef and carrot *in vacuo*, which had been hermetically sealed thirty-nine days before, after the fluid had been boiled, was opened on January 18, 1870.

This flask had been allowed to remain so long before it was opened because the fluid within showed no noticeable signs of change. There was no pellicle, and only a very small amount of granular material at the bottom of the flask.

On microscopical examination no distinct living things were found. Only a small quantity of motionless granular matter was seen.

Experiment 4.—A flask containing an infusion of hay, together with a few grains of phosphate of soda, *in vacuo*, which had been hermetically sealed seventeen days previously, after the fluid had been boiled, was opened on January 25, 1870.

The fluid itself was not turbid or cloudy, though it had become darker in colour. The bottom of the flask was irregularly lined with granular and slightly flocculent material.

On microscopical examination of two or three drops, there were seen many actively-moving monads; some bacteria of medium size; many quite irregularly-shaped particles in active movement; many flattened bits of protoplasmic-looking material with irregular and slightly curled edges, slowly moving, and ranging in size from $\frac{1}{10000}''$ to $\frac{1}{5000}''$ in diameter (other masses of this kind were distinctly hollow though mostly irregular in shape); and lastly there were several large irregular masses of fibres, the nature of which could not be determined.

2. *Infusions having an acid reaction.*

Experiment 5.—A flask containing a filtered infusion of turnip *in vacuo*, which had been hermetically sealed only *five* days previously, after the fluid had been boiled, was opened on December 15, 1869.

On the second day after the flask had been sealed, the previously clear solution began to exhibit a cloudy appearance. The next day a reticulated scum was seen on the surface of the fluid, which gradually became more manifest on the two following days. When the neck of the flask was opened, its contents were found to emit a most fœtid, sickly odour.

Microscopical examination revealed a very large number of bacteria and vibrionic-looking rods, some straight and others bent, some motionless and others exhibiting languid movements. These, mixed up with a thickly interlaced network of *Leptothrix* filaments, constituted the reticulated pellicle which was seen on the surface. The *Leptothrix* fibres were partly plain, and partly segmented; they had a precisely similar appearance to the vibrionic-looking filaments, with which in thickness they also closely agreed. The long filaments seemed, in fact, to be only developed forms of the shorter rod-like filaments. A large nucleated ovoid cell was also seen, $\frac{1}{1428}''$ in its longest diameter, as well as a smaller vesicle, enclosing a rod-like body.

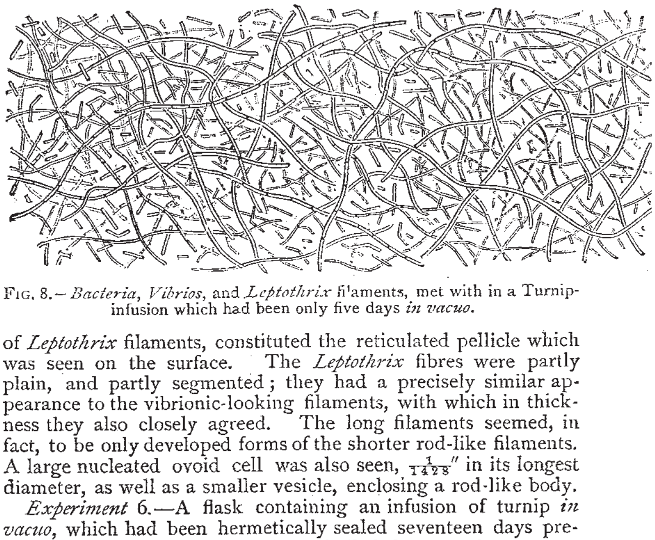

FIG. 8.—*Bacteria, Vibrios*, and *Leptothrix* filaments, met with in a Turnip-infusion which had been only five days *in vacuo*.

Experiment 6.—A flask containing an infusion of turnip *in vacuo*, which had been hermetically sealed seventeen days previously, after the fluid had been boiled for 20 minutes, was opened on January 25, 1870. The fluid never exhibited any distinct turbidity, and no pellicle formed on the surface; there was, however, an irregular covering of the bottom of the flask by fine granular matter, with here and there a small patch of filamentous-looking substance. No bad odour was perceived on opening the flask.

Unfortunately just as I was proceeding to examine the contents microscopically, nearly all the fluid was lost, including the filamentous-looking masses. Examination of a few drops of the fluid which remained showed a very large number of monads and bacteria; only a few of them were isolated and displayed movements; they were for the most part aggregated, either into spherical masses or else in the form of portions of a broken layer which presented traces of a *secondary organisation* similar to that represented in Fig. 1.

Experiment 7.—A flask containing an infusion of turnip *in vacuo*, which had been hermetically sealed seven days previously, after the fluid had been boiled for 20 minutes, was opened on February 4, 1870.

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* Continued from p. 177.

† An objective of this power was used throughout these investigations; it was an "immersion" glass (No. 9) of Nachet's make. All the objects were drawn, therefore, as seen with a magnifying power of about 600 diameters.

The solution itself was much clouded, and its surface was covered by a thick gelatinous pellicle.

On microscopical examination of the fluid it was found to contain a multitude of very active monads and bacteria. The thick gelatinous pellicle was also made up of an aggregation of these in the usual transparent mucoid material. In very many situations this uniform pellicle was undergoing a process of *secondary organisation*, such as I have already fully described as leading to the production of unicellular organisms, and such as was seen to a less extent in the last experiment.

Experiment 8.—A flask containing a very strong infusion of turnip *in vacuo*, which had been hermetically sealed fifteen days previously, after the fluid had been boiled for 15 minutes, was opened on February 28, 1870.

The solution itself was very cloudy, and there was on its surface a thick coriaceous sort of pellicle distinguished by closely set aggregations or islets of denser growth.

On microscopical examination the fluid was found to contain a multitude of very active monads and bacteria. The bacteria were almost more active than any I had before seen, and there were many different kinds. Some exhibited rapid serpentine movements, accompanied by flexions of the two segments of which they were composed; whilst the movements of others were rapidly progressive in straight or curved lines.

The pellicle was made up mainly of simple *Leptothrix* filaments (mostly without joints or evidences of segmentation); and the thicker islets were found to be produced by a more luxuriant growth in these situations of densely interwoven filaments.

The pellicle was found to be so tough and elastic that some of it could only be mounted as a microscopical specimen after it had been compressed for an hour or two, by placing a small weight on the covering glass.

On the same day that this solution was hermetically sealed *in vacuo*, two other portions of the same infusion were treated in a different manner for the sake of comparison. One (A) was enclosed, and sealed, in a flask with ordinary air and without the infusion having been boiled; another portion (B) was boiled for fifteen minutes, and when the solution was cool, so that the flask was filled with ordinary air as before, its neck was hermetically closed by the blow-pipe flame. The third portion (C), as above mentioned, after it had been boiled for fifteen minutes was sealed up *in vacuo*.

The changes which took place were as follows. Towards the close of the *second* day, solution A became cloudy, and twenty-four hours later that in B was in a similar condition. It was not till two days later that solution C became cloudy. Afterwards, till the fifteenth day, when they were all opened, solutions A and B underwent comparatively little change, only becoming rather more opaque, though no distinct pellicle was formed on either; in solution C, however, the pellicle continued to grow thicker and more distinct throughout the whole period. When opened the reaction of all three was still found to be slightly acid. In other respects their characters were as follows:

Odour.		*Nature of Contents.*
Somewhat sickly, with smell of baked turnip.	Solution A … …	A multitude of monads and bacteria of medium size, all very active.
Fragrant, like that of fresh turnip.	„ B … …	Small monad-like granules most numerous; bacteria scarce, and movements not very active.
Decidedly fœtid…	„ C … …	Monads and bacteria of many kinds, whose movements were extremely active. An enormous quantity of *Leptothrix* filaments.

The results of these comparative experiments are most interesting. The changes commenced first in the unboiled solution, as might have been imagined; then, in the two boiled solutions. We find them commencing in the solution in contact with air before they did in that which was contained *in vacuo*—the reason of this being not quite so obvious. But the changes in A and B were only able to advance to a certain extent, because, apparently, the space above the fluid being already filled with air, these changes, necessitating the evolution of gases as residual products, were only able to go on so long as the increased tension occasioned did not reach such a stage as to stop these molecular re-arrangements altogether. As might have been expected, the changes which took place in A were different from those which occurred in B. Those of A seemed to have been more thorough, giving rise to a much larger quantity of bacteria, and the somewhat sickly odour of this was also intermediate between the comparatively unchanged odour in A and the decidedly fœtid odour of B, in which such an enormous development of organisms had taken place. Here, then, the advantages of the vacuum seem to be most clearly shown.

After having read M. Pasteur's account, concerning the growth and development of fungoid organisms which had been placed in saline solutions,[*] it occurred to me that it would be a subject of much interest to determine whether any evidence could be obtained tending to show that organisms might even be evolved *de novo* in certain saline solutions. This, in fact, seemed to be a problem of very great importance; for, if otherwise suitable, the employment of such saline solutions would be attended by certain advantages. In the first place it was likely that the saline materials in solution would be far less injured by the high temperature of 100° C. than organic substances. And since, in working with a vacuum, we are able to get rid of the air altogether as a possible "germ" containing medium, so, with the view of simplifying our experiments, it becomes desirable that everything in our power should be done to diminish the number of possible pre-existing germs in the solutions employed. But this end, also, seemed likely to be best carried out by the employment of certain simple saline solutions. We should thus be able to get rid, as it were, of Buffon's "molecules organiques," which he supposed to pervade all organic matter that had been fashioned in a Living organism—and also of those ordinary organic molecules whose presence is supposed, even by M. Pouchet and other heterogenists,[†] to be absolutely necessary in order that "spontaneous generation" may occur. We should thus, indeed, best emerge from the circle of the organic, thus as far as possible elude the company of all those embarrassing molecules which the vitalist may choose gratuitously to endow with "vital" properties, and to regard as the chosen seat of a special "vital force," uncorrelatable with the ordinary physical forces. We may thus be best brought face to face with the problem—Whether the pre-existence of organic matter, which has been elaborated in pre-existing organisms, is, at present, absolutely necessary for the *de novo* origination of Living things; or whether, in fact, these may arise, more or less directly, by changes taking place in an aggregation of new formed molecules of an organic type, which have been themselves produced by the combination of some of the dissociated elements of the saline substances employed.

Just as nitrate of ammonia, carbonate of ammonia, free carbonic acid, and water, with a few saline substances, constitute the materials which—under the influence of the modified physical forces operating in the Living plant—are convertible into similar living vegetable protoplasm, so the problem which now presented itself was, whether under the influence of purely physical forces—acting upon solutions containing some such ingredients—re-arrangements might not be brought about amongst the elements of the substances dissolved and of the aqueous medium itself, resulting primarily in the formation of certain new complex molecules, which, secondarily, under the continued influence of similar physical forces[‡], are capable of permitting the occurrence of new modes of collocation resulting in the evolution of the minutest specks of Living Matter [§].

It resolved itself, in fact, into an inquiry whether Living things can now originate on the surface of our globe in that fashion after which alone (in accordance with the evolution hypothesis) they could have originated in those far remote geologic ages when Life first began to dawn upon the still heated surface of that rotating and revolving spheroid which now constitutes our planet. Before organic matter of the ordinary kind could exist organisms must have been present to produce it. Organisible compounds of a certain kind must, nevertheless, have preceded organisms. And just as chemists are now able to build up a great number of organic compounds in their laboratories, so it seems quite possible that some such mobile compounds may have been evolved by the agency of natural forces alone acting on the heated surface of the earth, at a period anterior to the advent of Living things.[*] We at present may, therefore, well wish to know, whether what is presumed to have taken place then may still take place now, since the affirmative solution of this problem would suffice to throw a halo of reflected light back through the ages, and would thus make that which is now a mere hypothesis, approximate as much as possible to the rank of one of the best established probabilities concerning the life-history of the globe on which we live.

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[*] Annales de Chimie et de Physique, 1862, p. 106.

[†] Who at the same time that they are heterogenists, are firm believers in a special "vital" force.

[‡] Those who wish to understand how incident physical forces are capable of bringing about such re-arrangement, should consult vol. i. chap. 2, of Mr. Herbert Spencer's "Principles of Biology."

[§] For the genesis of Life, we need only look after the origin of such a speck of Living Matter. This is all that would be required by the greater number of the most advanced physiologists of the day. Given a mere speck of living matter less than $\frac{1}{50000}$″ in diameter, and a Living thing may soon appear in the form of a *Vibrio*, a *Torula* cell, or a *Leptothrix* filament. By all such biologists the "vital" forces are held to be *molecular* forces, and such molecular forces are nought else than the resultant attributes of the particular

It was with a feeble hope of throwing light upon the above-mentioned subject that I commenced the series of experiments which are now to be detailed. These were at first somewhat tentative, but the success obtained at each step emboldened me to proceed in my endeavours to obtain Living things under more and more arduous conditions. In all cases the saline substances were carefully selected; one of the first requisites being that they should, at all events, contain the four fundamental ingredients of Living things: nitrogen, carbon, hydrogen, and oxygen. Therefore it was that in almost all cases an ammoniacal salt was one of the substances used, on account of its capability of supplying nitrogen. And, with the view of keeping up a sort of uniformity, phosphate of soda was employed as the second saline ingredient in as many of the solutions as possible. This was considered quite as suitable as any other salt, and as a phosphate it presented certain advantages.[†] It was deemed necessary, moreover, that a certain mixture of substances should exist, in order that there might be sufficient diversity amongst the elements coexisting in the solutions. These elements being then affected differently by the play of incident physical forces upon them, under their new modes of vibration thus excited, new and altogether different mutual affinities might become dominant, after the fashion so clearly indicated by Mr. Herbert Spencer[‡] in reference to other molecular re-arrangements. And these affinities *might* also be such as would tend to a colloidal rather than to a crystalloidal mode of aggregation. Concerning such probabilities, we doubtless have much to learn. Amongst saline substances, colloidal modes of aggregation seem to be favoured under certain sets of conditions, and crystalloidal modes of aggregation under certain other sets of conditions. Prof. Graham showed that this was the case with such mineral compounds as silica, the sesqui-oxides of iron, chromium, and other bodies. Then, again, this possibility of an isomeric modification is admirably exemplified by the now well-known tendency of cyanate of ammonia to become converted into the organic compound called urea. We are told in Watts's *Dictionary of Chemistry*[§] that after an aqueous solution of cyanate of ammonia has been prepared, the "liquid exhibits the reactions of a cyanate, but when *heated* or left to evaporate spontaneously, it is converted into urea." This would seem to show that the passage from the crystalloid to the colloid mode of molecular collocation is by no means a difficult one—that it may be brought about, in fact, by very slight determining causes.

That transitions of a reverse order may be effected from the one to the other state or mode of aggregation—and this, too, even with more complex substances—seems indicated by the fact that certain protein compounds may exist at one time in their usual colloidal state, and at another time as statical crystalline aggregates. The possibility of the assumption of the crystalline form by a certain number of these protein or colloidal substances is, indeed, now placed beyond all doubt.[||] As the most familiar instance of this I may mention the now well-known oblique rhombic *hematoidin* crystals and other crystalline forms obtainable from blood. And amongst these latter are to be included certain tetrahedral crystals discovered[¶] by Reichert, in connection with the placenta of the guinea-pig, the behaviour of which to reagents rendered it certain that they were of an albuminous or protein nature.[*] Chlorophyll, also, has been observed in a crystalline state by M. Trécul.[†] In these and in many other cases which might be cited, we have, apparently, to do with some mere alteration in the arrangement of molecules, and the crystalline form is to be regarded as possible when certain isomeric modifications are brought about in substances which ordinarily are non-crystallisable. No less an authority than M. Trécul, also, tells[‡] us that he has actually seen and watched a tetrahedral crystalline mass of this kind, which had been produced within the cells of the bark of the common elder (*Sambucus nigra*), gradually undergoing a modification in form at a certain part of a most startling nature. Whilst altering in shape, the part so altering was seen to become converted into a short fungoid filament which grew at the expense of the crystal. This change in form, then, could only be taken as the external sign of a much more profound molecular rearrangement taking place within the mass, whereby it was changed from a non-living albuminoid crystal into a Living and growing organism.[§] In this remarkable case there must have been not only a relapse into the colloidal mode of molecular aggregation, but a secondary assumption of a still more unstable mode of collocation, by means of which the mass was gradually converted into a living embryo fungus.

It is well, then, for us to bear these facts and statements in mind, whilst we enter into the kindred though somewhat different inquiry, whether, under the influence of suitable conditions, there is any disposition for the ultimate constituents of different saline substances, existing intermixed in a state of aqueous solution, to fall into new groupings or modes of collocation of a non-saline or colloidal nature. If this can take place, we should then have a new kind of decomposition with an almost simultaneous recomposition—a re-arrangement, in fact—giving birth to substances allied to those of the protein group. And it would be only rational for us to suppose that such new-formed protein substances would be as prone to undergo change as these substances are generally found to be. If ordinary protein substances, therefore, which have been built up as parts of Living things, are capable of going through certain Life-giving changes, it would be quite possible that the differently evolved protein—that which comes into existence "spontaneously," or without the influence of pre-existing living things—may go through similar changes. The molecular constitution of these two kinds of matter may be closely allied, and wherever Life-giving changes occur, we are entitled to look upon these as actions resulting from the influence of physical forces upon material collocations whose molecular constitution is of such a nature as to render them prone to undergo current re-arrangements. A series of actions and reactions occur between such material collocations and their environment, and as a result Living things appear and grow. This tendency to undergo change is inherent in colloidal substances. As Prof. Graham told us:—"Their existence is a continual metastatis. . . . The Colloidal is, in fact, a dynamical state of matter, the crystalloid being the statical condition. The colloid possesses ENERGIA. *It may be looked upon as the probable primary source of the force appearing in the phenomena of vitality.*"

B.—Fluids employed being Solutions of Saline Substances in Distilled Water.

Experiment 9.—A flask containing a solution (neutral) of crystallised white sugar, tartrate of ammonia, phosphate of ammonia, and phosphate of soda[||] *in vacuo*, which had been hermetically sealed nine days previously, after the fluid had been boiled for 20 minutes, was opened on January 4, 1870.

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atomic collocation which displays them. The speck of living matter is held to contain no newly created force—just as no one believes it to contain newly created material units. Such a germ or embryo Living thing, is only a new mode of collocation of pre-existing matter, and of pre-existing force or motion. Its properties—the "vital" phenomena which it manifests—are the results of the particular material collocation which exists, and of the "conditions" by which this is surrounded. A Living thing is a dynamic aggregate, and between such aggregate and its environment, there is continuous action and reaction so long as Life exists.

I have given the reasons for such views a little more fully in an article entitled "Protoplasm" (NATURE, Feb. 24, 1870), and I would again refer the reader to the views announced by Prof. Huxley and Prof. Tyndall (Note, p. 175).

[*] See *Appendix* to Mr. Herbert Spencer's "Principles of Biology."

[†] The presence of phosphates was found by M. Pasteur greatly to favour the growth of fungi in certain saline solutions. (Annales de Chimie et de Physique, 1862, p. 108.)

[‡] Principles of Biology, Vol. I. chap. ii., entitled, "The Action of Forces on Organic Matter."

[§] Vol. ii. p. 193.

[||] See an article on "Albuminous Crystallisation," in *British and Foreign Medical and Chirurgical Review*, Oct. 1853.

[¶] Beobachtungen über eine eiweissartige Substanz in Crystal-form:—Müller's Archives, 1849, p. 197.

[*] For an account of these reactions see *Brit. and For. Rev.*, loc. cit., p. 354.

[†] Comptes Rendus, t. lxi., p. 436.

[‡] *Ibid.*, t. lxi. (1865), p. 435.

[§] M. Trécul's own words are as follows:—"Lors de mes observations en 1860, j'avais reconnu que des corpuscles colorables en violet par l'iode remplacent frequemment les tétraèdres après la putréfaction, mais je ne vis pas à cette époque la transition des uns aux autres. Je fus plus heureux cette année; j'ai vu les tétraèdres s'allonger par un de leurs angles, et passe graduellement à nos singulières plantules en produisant une tigelle cylindrique. Dans ce cas le tétraèdre, arrondi ou encore anguleux, représente la bulbe. Le tétraèdre peut même s'effacer complétement, et ne laisser après lui qu'une plantule fusiforme ou cylindrique."

[||] The several ingredients were contained in this solution in the following proportions:—To 80 parts of water there were added 16 parts of sugar, 1 part of tartrate of ammonia, and ½ a part each of phosphate of ammonia and phosphate of soda. This solution, therefore, did not contain saline substances alone; the presence of sugar made it form a connecting link, as it were, between the solutions containing organic matter only, and those in which saline substances alone were contained.

Before the flask was opened the solution itself was clear and without the least trace of a pellicle on its surface, though for the last three or four days a very fine deposit was seen on certain parts of the bottom and sides of the flask.

When examined microscopically, a very few monads and bacteria were found in the first few drops of the fluid, which had been poured out before the whole was shaken. The remainder was then poured into a conical glass, and after having been allowed to stand for a time, the supernatant fluid was removed, and the last few drops containing the sediment were examined. In this were seen many bacteroid particles (*a*) and monads of different sizes, exhibiting the most active movements, as well as some irregular-shaped particles, also active. Many of the mere monad-like particles had the appearance of being very small *Torula* globules (*b*), and one cell of this kind was seen $\frac{1}{7500}''$ in diameter, and containing a nuclear particle in its interior. Many groups made up of three ovoid particles (*c*) were also seen, and also a dumb-bell-like body, all exhibiting slow movements. There were, moreover, motionless protoplasmic-looking masses—some cuboidal or more or less spherical and hollow, and others altogether irregular in shape, though appearing like masses of formless protoplasm ; also peculiar branched fibres with knob-like swellings at the termination of the branchlets, and lastly a small mass made up of a spirally-twisted fibre, similar to that (represented in Fig. 13) which was found more abundantly in subsequent experiments* where tartrate of ammonia and phosphate of soda were employed.

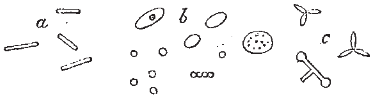

FIG. 9.—Organisms met with in Experiment 9.

Experiment 10.—A flask containing a solution† of acetate of ammonia and phosphate of soda, *in vacuo*, which had been hermetically sealed forty-two days previously, after the fluid had been boiled for 20 minutes, was opened on March 10, 1870.

The solution during this time had shown no signs of deposit, turbidity, or pellicle, and on microscopical examination of the fluid, no organisms of any kind were discovered.

Experiment 11.—A flask containing a solution‡ of oxalate of ammonia and phosphate of soda, *in vacuo*, which had been hermetically sealed sixty-one days previously, after the fluid had been boiled for 20 minutes, was opened on March 27, 1870. Its reaction was then found to be slightly acid.

The solution itself continued clear throughout, and presented no scum on its surface ; but, after a time, a very small amount of deposit made its appearance at the bottom of the flask, and latterly this had appeared as a small, irregular, and opaque whitish aggregation, with branch-like ramifications. It was very friable and easily broke up into a white granular material. Almost immediately after the neck of the flask had been broken, small acicular crystals appeared in abundance on and in the solution, varying from about ½ to 1 line in length.§

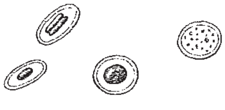

FIG. 10.—Fungus-spores found in Solution of Oxalate of Ammonia.

On microscopical examination, monads and altogether irregularly-shaped particles, showing tolerably active movements, were abundant. A few hyaline spherical vesicles were seen having no solid contents, and some of them were flattened at one pole. Three distinct fungus-spores were seen, and also another otherwise similar body in which there were small granules rather than a single nucleus. There was also a nucleated organism slightly larger, one of whose extremities was rectangular, whilst the other was rounded. In addition, there was a considerable quantity of white granular material which had resulted from the crumbling of large, though opaque white, masses of the same substance ; and also some semi-crystalline, opaque rhomboid plates.

Experiment 12.—A flask containing a solution* of tartrate of ammonia and phosphate of soda, *in vacuo*, which had been hermetically sealed eleven days previously, after the fluid had been boiled for 20 minutes, was opened on January 21, 1870. The reaction was then found to be still slightly acid.

No turbidity of the fluid was observed, and no scum formed on its surface, though a very slight deposit gradually collected at the sides and bottom of the vessel, and amongst this there was seen, during the last six or seven days, a small white, flocculent mass, which gradually increased in size.

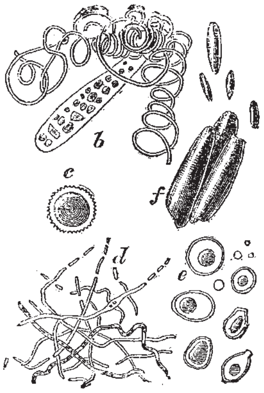

FIG. 11.—Spiral and Confervoid-looking Filaments, with Fungus-spores and Crystals, from a Tartrate of Ammonia Solution.

On microscopical examination of the white mass, this was found to be made up for the most part of a densely interlaced and spirally-twisted fibre, almost precisely similar to what was alluded to in Experiment 9 and to what is represented in Fig. 13, This was colourless, highly refractive, quite homogeneous, and apparently solid. In one place there was seen emerging from amongst the spiral fibres an elongated chamber (*b*) resembling a spore case, and containing many separate protoplasmic-looking masses. At one border of this spirally-twisted fibre-organism, there were a number of other filaments (*d*) about $\frac{1}{20000}''$ in diameter, and containing irregular masses of protoplasm in their interior. These were colourless confervoid-looking filaments.

A few moving monad-like particles were seen, and in the sediment there were many motionless aggregations of such particles imbedded in an almost invisible and scanty jelly-like matrix. In these masses rounded or ovoid fungus-spores (mostly with large nuclei in their interior, in various stages of formation) existed pretty abundantly (*e*). Some of the spores showed a slight neck-like projection and flattening at one extremity, as though they were about to germinate. In addition another much larger spore (*c*) was found. Some of the rounded crystals which were met with in this solution are also represented (*f*).

Experiment 13.—A flask containing a solution† of tartrate of ammonia and phosphate of soda *in vacuo*, which had been hermetically sealed twenty days previously, after the fluid had been boiled for 20 minutes, was opened on February 15, 1870. The reaction of the fluid was then decidedly acid.

The fluid itself showed no signs of turbidity, and there was no trace of scum on its surface. Small whitish flocculent shreds had, however, been seen at the bottom of the flask for the last twelve or fourteen days, during which time they seemed very slowly to increase in size. Some smaller sedimentary particles were also seen at the bottom.

On microscopical examination some of the white shreds were found to be composed of comparatively large masses of the small algoid filaments which were met with in the last experiment ; whilst others were made up of an aggregation of fungoid spores with an abundant mycelium which had been developed from them. The spores were precisely similar to those which were found in the last solution. There they were about to germinate, and here they had germinated into a fungus of the *Penicillium* type. In one mass the mycelium had produced four or five much larger filaments, terminating in artichoke-like heads of different sizes, bearing naked spores. Though two of the organisms met with in the last experiment were here reproduced, this was not the case with the spirally-twisted fibre organism.

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* This fibre growth was twisted around a paper-fibre, but there is little doubt that it had simply grown round this as a mere foreign body. Every part of the paper fibre showed the most distinct colour reactions with the polariscope, though the spirally-twisted fibre did not show a trace of such reaction.

† Reaction neutral. ‡ Reaction neutral.

§ Two days before this flask was opened, it was removed for a few hours into another room, where the temperature was lower. The agitation of the fluid, and perhaps in part the lower temperature, soon resulted in the formation throughout the fluid of a number of large acicular crystals from ½ to 1 inch in length. These disappeared in the evening as soon as the temperature of the solution was again raised to about 80° F. The greatly superior size of the crystals produced *in vacuo* is worthy of note.

* Reaction slightly acid. † Reaction slightly acid.

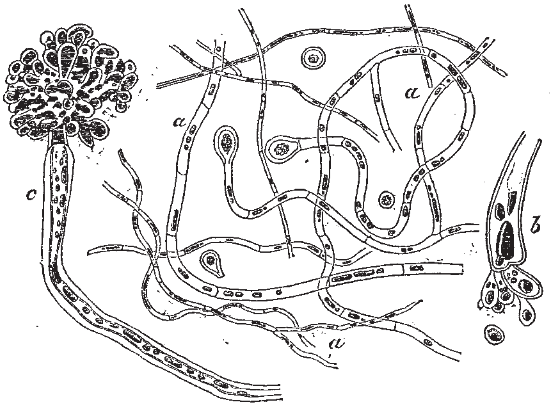

FIG. 12.—Fungus found in the Solution containing Tartrate of Ammonia and Phosphate of Soda.

A few actively moving granules and particles of various shapes were seen, though, as in the last solution, there was nothing resembling a bacterium. Spherules which seemed to represent different stages in the development of the fungus-spores were met with, varying in size from that of an almost inappreciable speck up to that of the perfect spore, which itself varied considerably in size at the time that it began to germinate. In one of these fungus-spores which was about half grown, the nuclear particle within was seen actively moving from end to end of the cell.*

Experiment 14.—A saturated solution of tartrate of ammonia and phosphate of soda *in vacuo*, prepared in same manner as the last solution and at the same time, though opened on the thirty-fifth day, yielded no organisms of any kind.

Experiment 14*a*.—(In this and in the following experiment the solutions were not contained *in vacuo*, but were intended rather to throw light upon the question as to whether the vacuum was favourable or prejudicial to the appearance and growth of organisms in these saline solutions.)

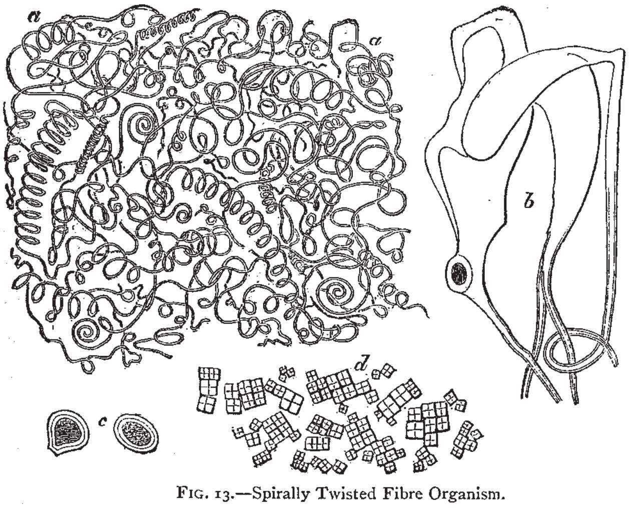

FIG. 13.—Spirally Twisted Fibre Organism.

A solution of tartrate of ammonia and phosphate of soda in distilled water was boiled for 20 minutes, and was then allowed to cool, so as to become filled with air at ordinary atmospheric pressure (which might have contained living germs, since no precaution was taken to destroy them). The neck of the flask was then hermetically sealed, and this was not opened till the thirty-eighth day, when the fluid was found to have a decidedly acid reaction.

The fluid never showed any signs of turbidity, and no pellicle formed on its surface, though a small white flocculent mass had been seen at the bottom of the flask for three weeks, which very slowly increased in size.

The white mass (Fig. 13, *a*) was picked out, and on microscopical examination it was found to be made up for the most part of a spirally-twisted fibre organism, very similar to that which was produced in a similar solution *in vacuo*. The spiral twisting was, however, even more marked, and the fibre in many places was somewhat thicker.*

In addition, two or three small fungus-spores were seen, very similar to those met with in Experiment 12; and there were also some confervoid-looking filaments with irregular masses of protoplasm in the interior, occurring sparingly here and there, similar to those which were met with in much larger quantity in the former experiment. Four or five larger cells were seen with very thick walls, closely resembling the sporangia of some fungi, and in one of them, measuring $\frac{1}{1000}''$ in diameter, many granules were present exhibiting the most active molecular movements. The contents of the other cells could not be made out, as they were so much obscured by the fibre organism in the midst of which they were imbedded.

Experiment 14*b*.—A solution of tartrate of ammonia and phosphate of soda in distilled water, without having been boiled, was exposed to the air † in a flask, and was then examined microscopically on the thirtieth day. The re-action of the fluid at this time was neutral.

There was no pellicle on, or opacity of the fluid, but a small whitish mass of matter had been seen at the bottom of the flask for the last fortnight, which slowly increased in size, till at last it formed a mass bigger than a mustard seed.

On microscopical examination this whitish flocculent matter was found to be made up principally of an enormous aggregation of *Sarcina*-like material, the divisions of which were rather more sharply defined though they were about equal in size to the *Sarcina* which is occasionally met with in urine.

Several fungus-spores were also seen (Fig. 13, *c*) larger than, though otherwise similar to, those met with in *Experiments* 12, 13, and 14*a*. There were none of the confervoid-looking filaments or of the spirally-twisted organisms.

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* In Experiments 12 and 13, the actual strength of the saline solutions was not known, but in these as well as in Experiments 14*a* and 14*b*, there may have been about 15 grains of tartrate of ammonia, with about 5 grains of phosphate of soda to an ounce of water.

* It has been suggested to me by a friend whose opinion carries great weight with it, that this is not an organism which had grown in the solutions, but rather some non-living accidental product which had gained access to the solutions. This was a suggestion which deserved a most attentive consideration, more especially as in two other experiments, which will not be cited, foreign bodies were found in the solutions. Are these spiral-fibre masses, then, mere non-living *débris* of some kind? It was suggested that they were spiral ducts of some plant broken up and modified by the boiling process which they had undergone.

With reference to this question it seems most desirable to state, in the first place, that such a spiral-fibre mass has been met with four times in solutions containing a mixture of tartrate of ammonia and phosphate of soda, though never in solutions containing tartrate of ammonia alone, and in fact it has never been found in any other kind of solution except in one whose chemical constitution was almost precisely similar to the mixture above named. This seemed to indicate that it might have been contained within or upon the crystals of phosphate of soda. Successive solutions, however, of many of these in a watch-glass have shown no trace of such fibre-masses (and it may be well to add, perhaps, that a similar statement holds good for the crystals of tartrate of ammonia). These masses of spiral fibre, found only in solutions of a given chemical constitution, have been seen to increase in size from week to week. The Rev. M. J. Berkeley, who was kind enough to examine my specimens, could not identify them with any known cryptogamic organisms.

If they were really altered spiral ducts, then, seeing that they have only been met with in solutions of a certain chemical constitution, they ought to have been contained in the saline substances employed. But an examination of such saline substances as above stated, does not show a trace of these fibre-masses. All the spiral ducts which I have examined, moreover—even after boiling—polarise beautifully, whilst these spirally twisted fibre-masses do not give the least trace of colour reactions with polarised light. And lastly, in certain parts the apparently solid spiral fibre seems to become decidedly tubular, and in other places it widens out into flat expansions of a peculiar character. In one of these expansions (Fig. 13, *b*) differentiation had apparently taken place, which had led to the production of a spore-like body.

A somewhat similar twisted fibre-organism was met with in Experiment 16, though here it was evidently in an embryonic condition. (Fig. 15.) It seemed to be then arising by a process of differentiation taking place in a pellicular mass.

† A piece of paper merely, was loosely inserted into the mouth of the flask with the view of keeping out as much dirt as possible.

Experiment 15.—A flask containing a solution of a potash-and-ammonia alum, and of tartar emetic, *in vacuo*, which had been hermetically sealed twenty-eight days previously, after the fluid had been boiled for fifteen minutes, was opened on March 17, 1870. The fluid then had a decidedly acid reaction.*

The solution continued clear throughout; there was no trace of a pellicle and no deposit at the sides, though a whitish flocculent mass was seen at the bottom of the flask after the first fortnight, which gradually increased in amount, and at last formed a mass about $\frac{1}{8}$″ in diameter.

On microscopical examination the white mass was found to be made up of aggregations of variously sized and irregularly shaped protein-looking particles which were imbedded (*b*) in a most distinct hyaline jelly-like material. The granules were highly refractive, altogether irregular in shape, and they varied in size from $\frac{1}{3000}$″ up to $\frac{1}{5000}$″ in diameter. Though most of the particles were motionless and imbedded in the jelly, very many were seen exhibiting active and independent movements; some of these were in the form of little double spherules (*d*), and a very few others resembled bacteria about $\frac{1}{8000}$″ in diameter, though they did not possess the accustomed joint.

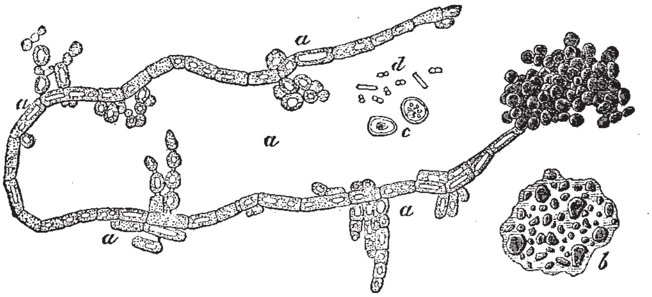

FIG. 14.—Fungus met with in a solution containing Potash-and-Ammonia Alum, with Tartar Emetic.

Three fungus-spores with thick double walls were seen. Each these was about $\frac{1}{3300}$″ in diameter. Within one of them there were only a number of granular particles (*c*), but within each of the other two there was a large and somewhat irregular nuclear mass.

In addition there was found the complete fungus which is represented in the figure (*a*), with all its spores. In a portion of one of the granular aggregations, a mass of about thirty spores seemed to be undergoing evolution in a part of the mucoid material through which some fine granules were disseminated.

Experiment 16.—A flask containing a solution of carbonate of ammonia and phospate of soda *in vacuo*, which had been hermetically sealed thirty days previously after the fluid had been boiled for twenty minutes, was opened on March 1, 1870. The fluid was then found to have a very slightly alkaline reaction.

The fluid had continued clear and no pellicle had formed on its surface, though a light granular deposit had slowly collected in small quantities on the bottom and sides of the flask.

On microscopical examination, bright highly refractive moving particles, very similar in appearance to those of milk, were met with, of all sizes varying between $\frac{1}{30000}$″ and $\frac{1}{5000}$″ in diameter. There were also numerous crust-like aggregations of such particles. Small *Torula* cells, the smallest being about $\frac{1}{15000}$″ in diameter, were very abundant. They were either single or double, and each cell contained a distinct nuclear particle; some of the larger ones, indeed, contained two. All these cells exhibited very slight oscillating movements. Two cellular looking bodies, each about $\frac{1}{2000}$″ in diameter, and having granular contents, were also seen; and, in addition, there were two or three patches of a peculiar spirally twisted fibre-like organism, growing in portions of the granular crust, and apparently representing an embryonic condition of a spiral fibre, closely resembling those met within previous experiments. Neither of these gave the smallest trace of a colour reaction with the polariscope.

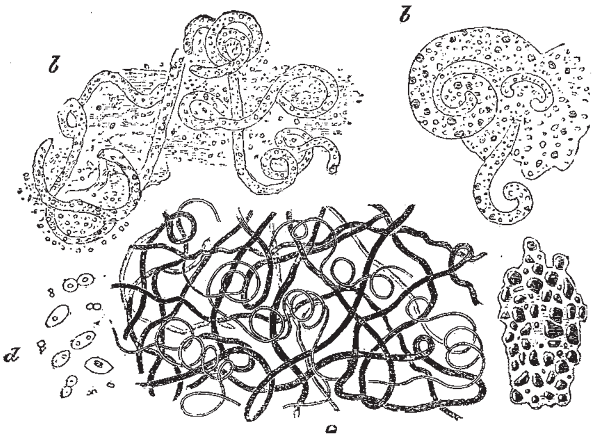

FIG. 15.—Embryonic condition, and also more mature stage, of a Spiral-fibre Organism met with in a solution of Carbonate of Ammonia and Phosphate of Soda.

B.—*Experiments in which the fluids employed were raised to a temperature of from* 146° *to* 153° *C. for four hours, after all air had been exhausted and the flasks had been hermetically sealed.*

A temperature of 100° C. has been the degree of heat to which all the fluids in the experiments hitherto related have been subjected. It has been previously found that none of the lower organisms so treated, and which had been afterwards examined, were able to survive an exposure for a few seconds to such a degree of heat. They had nearly all been destroyed, in fact, at a temperature many degrees short of this. Many different kinds of organisms have been submitted to this test, and without the occurrence of any exceptions* such a degree of heat has always proved fatal to them. Looking, therefore, on the one hand, at the uniformity in the experimental evidence, which has itself extended over a wide basis, and, on the other, at the comparative uniformity in fundamental nature and property existing between all the lowest kinds of Living things, which are almost wholly made up of a more or less naked living matter or protoplasm, it is only reasonable for us to conclude, until direct evidence can be adduced to the contrary, that that which holds good for the many without exception may prove to be a rule of universal application. Therefore it was that the Societé de Biologie (and M. Pasteur himself for a long time) assumed that none of the lower kind of organism could survive in a fluid which was raised to a temperature of 100° C.

No evidence has as yet been adduced which is capable of shaking the validity of this conclusion, and the experiments just related are much stronger in favour of the view that the organisms found in my experimental fluids were there evolved *de novo* than were all the negative results in the experiments of Schwann (upon which so much stress was formerly laid) in proving the impossibibility of such a mode of evolution. And yet Schwann's experiments were deemed by many so conclusive that they were thought to have upset the doctrine of heterogeny. The fluids with which he experimented were only exposed to a temperature of 100° C., and, working under a particular set of conditions which are considered to be adverse to the occurrence of evolutional changes, he found no organisms therein when his flasks were opened. I, on the contrary, subjecting my experimental fluids to the same temperature, though exposing them subsequently to quite different conditions, which I suppose to be more favourable for the occurrence of evolutional changes, do find organisms in the fluids when the flasks are opened. His negative results *may* be only applicable to the particular fluids and the particular conditions under which he worked; but my positive results, and those of many other experimenters, may be considered to have a most important bearing upon the settlement of the general doctrine. It becomes simply a question as to whether the conditions which were formerly believed sufficiently stringent to destroy all pre-existing Living things within the experimental flasks are in reality adequate to effect this. Can the standard of vital resistance be raised? If the old landmarks cannot be shown to be false, then there is very far more evidence of all kinds in favour of, than there is against, the occurrence of "spontaneous generation."

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* This solution was prepared one evening when I had been busy in devising several other mixtures with which I deemed it desirable to experiment. At the time I thought I possessed a pure potash alum, and by some strange oversight I had failed to recognise that, if this had been the case, I should have been employing a solution which contained no nitrogen. Having once planned what mixtures I would use, I did not further think of each of them analytically. It was not, therefore, till my attention was called by Dr. Sharpey to the assumed absence of nitrogen in the above solution, that I became aware of this. It seemed very incredible that an organism should have been produced in a solution containing no nitrogen. I then had some of my supposed potash alum carefully tested, and it was found to contain a considerable quantity of ammonia. I then also learned that as ammonia-alum is now the alum of commerce, it is very difficult to get a pure potash alum.

* No exceptions, that is, amongst such organisms as are met with in infusions. The only known exceptions to that rule being met with in the case of seeds naturally provided with a hard *testa*, and after these had undergone an extreme amount of desiccation.

But in order, still further, to put this question beyond the region of doubt, I gladly availed myself of Prof. Frankland's proffered aid. He very kindly offered to procure a perfect vacuum in my flasks, and then, after these had been hermetically sealed, to expose them and the fluids which they contained for some time to a temperature of about 150° C. This temperature for a fluid is so very far in advance of that which is at present believed to be destructive to all the lower organisms, that it is perfectly fair for us to presume, till evidence be adduced to the contrary, that Living things would be completely destroyed by an exposure to such a temperature even for a single minute.

It seemed desirable to try different kinds of solutions in this way, and I therefore asked Dr. Frankland to be kind enough to submit four flasks and their contents to this most stringent test. In order that they might be representative of the solutions with which I had already been working, one was to contain a freshly prepared and filtered infusion of turnip; another a solution of sugar, tartrate of ammonia, and phosphate of soda in distilled water; another a solution of tartrate of ammonia and phosphate of soda alone in distilled water; whilst the last was to contain carbonate of ammonia and phosphate of soda in distilled water.

The second of these solutions was submitted to these conditions by Dr. Frankland, on Feb. 11, 1870, together with two others, one containing turnip juice, and the other carbonate of ammonia and phosphate of soda. On the following day I received a letter from Dr. Frankland, in which he had written as follows:—"Yesterday, I exposed the three liquids to a temperature of 150° C. for four hours. On taking them out of the digester this morning two were broken; one had probably burst with the pressure of carbonate of ammonia vapour, the other had received some slight shock which had broken off the extreme point of glass where it was drawn off before the blowpipe. The third, containing the tartrate of ammonia, sugar, and phosphate of soda, I send along with this, but fear you will not consider its contents favourable for your operations, part of the sugar having apparently been converted into caramel."

A few days afterwards (on Feb. 15) Dr. Frankland submitted the three other solutions to a similar treatment, and he has kindly furnished me with the following statement of the conditions to which they were subjected:—

"Each liquid was placed in a glass tube about $\frac{3}{4}$ inch in diameter, 9 inches long, and closed at one end by fusion of the glass. The open end of the tube was then drawn out so as to form a thick capillary tube, which was afterwards connected with a Sprengel's mercurial pump. The action of the pump soon produced a tolerably good vacuum, when on gently warming the liquid, the latter began to boil, its vapour expelling the last traces of air from the apparatus. After the boiling had been continued for several minutes, the tube was hermetically sealed at the capillary part.

"Three tubes were prepared in this way, containing respectively—

"1. Turnip juice;

"2. Solution of ammonic tartrate and sodic phosphate;

"3. Solution of ammonic carbonate and sodic phosphate.

"The vacuum in tubes Nos. 1 and 2 was so perfect as to render them good water-hammers. In the third tube the vacuum was not so good, owing, doubtless, to the evolution of carbonic anhydride from the ammonic carbonate.

"The three tubes were now placed in the wrought iron digester, described by me in the Philosophical Transactions for 1854, page 260. It consists essentially of a cylindrical iron vessel, with a tightly fitting cover, which can be securely screwed on to it. Through the centre of the cover passes an iron tube, which descends half way down the centre of the cylinder. This tube is closed at bottom, and contains a column of mercury about an inch long, and a thermometer plunged into the mercury shows the temperature of the liquid inside the digester.

"Water being now poured into the digester until it covered the tubes, and the cover having been screwed on, heat was applied by means of a gas stove.

"The temperature was allowed to rise to about 150° C., and was maintained between 146° and 153° C. for four hours, and it is almost needless to say that every part of the sealed tubes and their contents was exposed to this temperature during the whole time. The glass tubes, though of moderately thick glass only, ran no risk of fracture, because the pressure inside them was approximately counter-balanced by the pressure of steam outside.

"After cooling, the tubes were removed from the digester, when it was found that the turnip juice had become discoloured, and the liquid no longer acted as a water-hammer, showing that the vacuum in the tube had been impaired. The contents of the two remaining tubes were apparently unaltered, the vacuum in No 2. being as perfect as ever."

Experiment 17.—The tube containing the infusion of turnip was opened at the end of the twelfth day.

When received from Dr. Frankland the fluid had been changed to a decided, but light brown colour, and there was some quantity of a blackish brown granular sediment at the bottom, though the solution was free from all deposit when placed in the digester. After this tube was suspended in the warm place, as the others had been, it remained in the same position till it was taken down to be opened. A slight scum or pellicle was observed on the surface—covering this partially—on the sixth day. During the succeeding days it did not increase much in extent, though it became somewhat thicker. Although very great care was taken, still the slight movement of the flask, occasioned in knocking off its top, caused this pellicle to break up and sink to the bottom.[*]

The contents of the flask emitted a somewhat fragrant odour of baked turnip, and the reaction of the fluid was still slightly acid. On microscopical examination, there was found very much mere granular *débris* of a brownish colour, which probably represented the brownish sediment seen when the tube was removed from the digester. There were, also, a very large number of dark apparently homogeneous reddish brown spherules, mostly varying in size from $\frac{1}{7500}''$ to $\frac{1}{20000}''$ in diameter, partly single and partly variously grouped; the nature of these was doubtful though they were probably concretions of some kind. There were also other indeterminate flat and irregular masses, which seemed more to resemble protoplasmic substance in its microscopical characters.

In addition, many irregular and monad-like particles were seen in active movement, though there were no distinct bacteria.

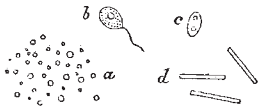

FIG. 16.—*Tailed Monad* and *Torula* Cell from a Turnip Solution which had been exposed to a temperature of 146°—153° C. for four hours.

Several rod-shaped bodies $\frac{1}{2000}''$ in length (*d*) were seen, however, resembling ordinary bacteria, except that they were unjointed and motionless.[†] In one of the drops examined there was a delicate tailed monad in active movement—a specimen of *Monas lens*, in fact, $\frac{1}{7500}''$ in diameter, having a distinct vacuole in the midst of the granular contents of the cell. Another ovoid body was seen, about the same size, without a tail and motionless, though it contained two nuclear particles within.[‡]

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[*] It was owing to the appearance of the pellicle and the seeming likelihood of its breaking up and sinking to the bottom if allowed to remain, as I had known others do, that I was induced to open this tube so early. I thought it possible that nothing else might form afterwards. I felt anxious to be able to examine this pellicle before it got mixed with the granular matter at the bottom.

[†] The bacteria which appear in a simple solution of tartrate of ammonia, however, frequently remain motionless for a very long time, and the *bacteridia* of Davaine are both unjointed and motionless.

[‡] Although these were the only bodies of this kind actually seen, it is worth noting that only five or six drops of about the whole ounce and a half of fluid were submitted to examination. This solution was undoubtedly examined rather prematurely. In another turnip solution which has been subsequently exposed in Dr. Frankland's digester to a temperature of 146° C. for a shorter time, and which was opened on the 67th day (the details of which I shall

Experiment 18.—The tube containing white sugar, tartrate of ammonia, and phosphate of soda in distilled water, was opened on the fortieth day after it had been heated in the digester.

When received from Dr. Frankland, this solution, instead of being colourless, was of a dark brownish-black colour, not unlike that of porter, this change of colour being apparently due to the conversion of some of the sugar into caramel; though it was free from any notable deposit. After about the fortieth day a thick iridescent scum gradually formed over the whole surface‡, and continued visible for more than a week. It afterwards disappeared, and then I noticed for the first time a large quantity of a brownish-black sediment at the bottom of the flask. No scum again formed on the surface, and no other change was seen to take place in the fluid.

When opened there was no very appreciable odour, though the reaction of the fluid was strongly acid.

On microscopical examination, the deposit was found to be made up in great part of dark, reddish-brown, or ruby-red coloured globules of various sizes, partly single, and partly in various kinds of aggregation. They varied in size from a minute speck $\frac{1}{20000}''$ in diameter up to large spherule $\frac{1}{1428}''$ in diameter. They presented no trace of structure, and were apparently quite homogeneous. Although larger, they resembled in other respects those which had been met with in the turnip solution. Other bodies, however, were seen, which presented much more obvious evidence of being concretions. They were mostly light brown in colour, some of the smaller somewhat resembling cells, with granular contents, whilst some of the larger, about $\frac{1}{2000}''$ in diameter, showed concentric markings, with or without the presence of a darker central nucleus of varying size. Some again were composite structures—each spheroidal as a whole, though made up of a close radiating aggregation of ovoidal bodies around such a central nucleus. None of these spherules showed any colour reactions with the polariscope. I regarded them all as non-living concretions of a doubtful nature

Two fresh looking fungus-spores were seen, however, of the most unmistakeable character. One, apparently just about to sprout, was $\frac{1}{7500}''$ in diameter; it had thick walls and a large central nucleus $\frac{1}{12000}''$ in diameter. The other was a smaller and more delicate-looking body, having more the appearance of a *Torula* cell. There were also some figure-of-eight-shaped bodies about $\frac{1}{20000}''$ in diameter, which were moving about most actively.

In addition, there were a multitude of particles altogether irregular in shape, in most active movement, having a protoplasmic appearance. Some were altogether irregular particles others were larger and more elaborate masses; whilst others—still exhibiting slow movements—were lozenge-shaped, or more or less cuboidal.

Experiment 19.—The tube containing tartrate of ammonia and phosphate of soda in distilled water was opened on the sixty-fifth day.

When received from Dr. Frankland, the solution in this tube was quite colourless, clear, and free from visible deposit. About the fifth or sixth day, however, after it had been suspended in a warm place, a number of small, pale, bluish-white flocculi made their appearance throughout the solution, and continued always in the same situation except when the fluid was shaken,—owing apparently to their specific weight being the same as that of the fluid itself. The contents of the flask were repeatedly scanned with the greatest care with the aid of a lens, though nothing else could be seen until about the expiration of a month. Then there was observed, attached to one of the flocculi about $\frac{1}{4}''$ from the bottom of the vessel, a small, opaque, whitish speck, little bigger than a pin's point. This increased very slowly in size for the next three or four weeks, and then another smaller mass also made its appearance. At the expiration of this time the larger mass was more than $\frac{1}{8}''$ in diameter, and both could be and were seen by several people with the naked eye. In the last three weeks previous to the opening of the flask it was often remarked that the mass did not appear to have at all increased in size.

Before the flask was opened it was found that it only acted as a water-hammer to a trifling extent, though when the narrow end of the flask was broken off there was a slight dull report, and a quantity of small particles of glass were swept by the in-rush of air into the fluid. There had still, then, been a partial vacuum in the flask. The reaction of the fluid was found to be slightly acid.

This flask was opened in Dr. Sharpey's presence. He had examined the white masses previously with a pocket-len , and when the flask was broken the larger white mass issued with some of the first portions of the fluid, which were poured into a large watch-glass. This was at once taken up on the point of a penknife and transferred to a clean glass slip, when it was immersed in a drop of the experimental fluid and then protected by a thin glass cover. On microscopical examination we at once saw that the whitish mass was composed of a number of rounded and ovoidal spores, with mycelial filaments issuing from them in all stages of development. The spores varied much in shape and dimensions; the prevalent size being about $\frac{1}{3500}''$ in diameter, though one was seen as much as $\frac{1}{2000}''$ in diameter. They all possessed a single rather large nucleus, which was mostly made up of an aggregation of granular particles. Some were just beginning to develope mycelial filaments, and others had already given origin to such filaments about $\frac{1}{4500}''$ in diameter, in which there were scattered some colourless protoplasmic granules, but no vacuoles. Contiguous to these fresh and evidently Living portions of the plant, there were other parts in all stages of decay, in which the remains of the filaments were seen in the form of more or less irregular rows of brownish granules representing the altered protoplasmic contents of a previous filament whose walls were now often scarcely visible. Subsequently the smaller white mass was picked out, and this was found to contain some living mycelium and spores, and also a considerable patch of decaying filaments, in connection with which ther was a long and broader filament bearing at its distal extremity a large aggregation of more than 100 spores, quite naked, and very similar in character to those from which the mycelial threads arose. This plant was evidently a *Penicillium* quite similar to what had been obtained from a tartrate of ammonia and phosphate of soda solution on a previous occasion after twenty-one days (*Experiment* 13), and its spores were also similiar to those which had appeared in another solution (*Experiment* 11) of the same kind after eleven days.

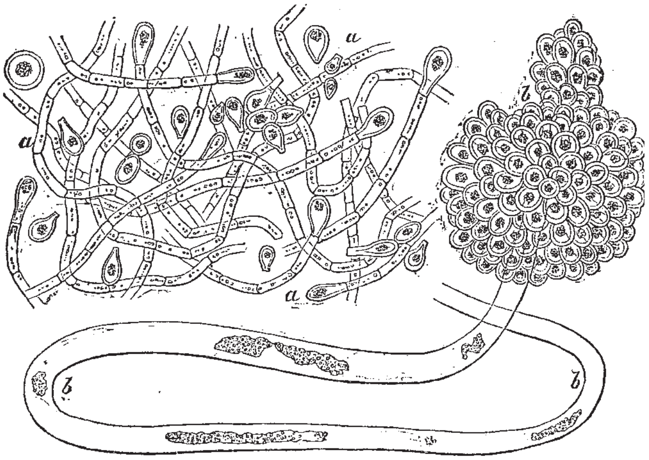

FIG. 17.—Fungus obtained from a solution of Tartrate of Ammonia and Phosphate of Soda which had been exposed to a temperature varying between 146° and 153° C. for four hours.

The delicate flocculi which first made their appearance in the solution, and which persisted throughout, seemed to be made up of aggregations of the finest granules, which, however, became almost invisible when the flocculi were mounted in glycerine and carbolic acid.

Experiment 20.—The tube containing carbonate of ammonia and phosphate of soda in distilled water, was opened on the thirtieth day in the presence of Prof. Huxley.

When this flask was received from Dr. Frankland, the fluid was somewhat whitish and clouded. During the last ten days a thin pellicle had been seen gradually accumulating on its surface, and in the latter four or five days this increased much in thickness, and gradually assumed a distinct mucoid appearance. The fluid itself was tolerably clear, though an apparent turbidity was given by the presence of a fine whitish deposit on the sides of the glass.

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afterwards publish), *Torula* cells, and fungus-spores with developing filaments, were formed in very large numbers, in company with other living organisms.

* This was much larger than that exposed in the other three vessels, owing to the fluid being contained in a small flask instead of in a tube.

When the flask was opened, the reaction of the fluid was found to be neutral.

Portions of the pellicle were at once transferred to a glass microscope slip, and then, protected by a covering glass, were submitted to a prolonged microscopical examination.* A number of little figure-of-eight particles, each half of which was $\frac{1}{20000}''$ in diameter, were seen in active movement, even in situations where they could not have been influenced by currents. The portions of the pellicle were made up of large, irregular, and highly refractive protein-looking particles imbedded in a transparent jelly-like material. The particles were most varied in size and shape, being often variously branched and knobbed. There were also seen several very delicate, perfectly hyaline, vesicles about $\frac{1}{2000}''$ in diameter, these being altogether free from solid contents.

A subsequent and most careful examination of a considerable quantity of the granular matter of the pellicle which had been mounted on two microscope-slips,† and at once protected by surrounding the covering glasses with cement, revealed five spherical or ovoid spores the average size of which was about $\frac{1}{3300}''$ in diameter. They all possessed a more or less perfectly-formed nucleus, and all showed a most distinct doubly-contoured wall. One of the smaller of them showed that it had reached a stage where it was about to germinate. In addition, one small mass of *Sarcina* was seen, not very distinctly defined, owing to its being still in a somewhat embryonic stage.

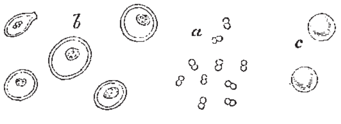

FIG. 18.—Fungus-spores found in a Carbonate of Ammonia and Phosphate of Soda Solution which had been exposed to a temperature varying from 146° to 153° C. for four hours.

H. CHARLTON BASTIAN

(*To be concluded.*)

NEW OBSERVATORY AT THE MAURITIUS

(*Communicated.*)

HIS Royal Highness the Duke of Edinburgh and his Excellency Sir Henry Barkly, attended by their respective suites, arrived at the site of the New Observatory at half past ten on Monday morning, May 30th, and were received by the President and Council of the Meteorological Society.

The architect of the building, Mr. Bowdler, of the Surveyor General's Department, and Mr. Horne, of the Royal Botanical Gardens, had elegantly decorated the grounds and the enclosed space around the massive stone.

The President, Captain Russell, R.N., read and presented the following address:—

"*To Captain His Royal Highness* ALFRED ERNEST ALBERT, *Duke of Edinburgh, Earl of Ulster, Earl of Kent, K.G., K.T., G.C.M.G., G.C.S.I., R.N., &c.*

"May it please your Royal Highness,

"We, the President and Council of the Meteorological Society of Mauritius, beg leave to approach your Royal Highness with the assurance of our loyalty to the Crown, and of our devoted attachment to Her Majesty the Queen and the Royal Family.

"We desire to offer to your Royal Highness a cordial welcome to these shores.

"Mauritius being admirably situated for meteorological and magnetical observation, it has long been the ardent wish of the Society that an Observatory, fully equipped wtth instruments of the most approved construction, should be permanently established for that purpose.

"Through the wise and liberal policy of the late Sir William Stevenson, and more immediately that of our present Governor and Patron, his Excellency Sir Henry Barkly, the moment for commencing the principal building has now arrived.

"We therefore hail with joy the auspicious occasion which allows us to request that your Royal Highness will be pleased to lay the Foundation Stone.

"Meteorological and magnetical researches, having for one of their main objects the safety and welfare of Navigation, touch closely the commercial prosperity of the world, and link together men of every nation by the cords of a common interest. Your Royal Highness, therefore, being not only an Officer in the Naval Service of a Queen whose ships traverse every sea, and whose Dominions extend to the remotest shores, but also the Son of an Illustrious Prince, who was ever foremost in encouraging Science, there could not, we venture to to think, be a more fitting Monument of the visit of your Royal Highness to Mauritius than a building to be specially devoted to objects with which your Royal Highness's experience cannot fail to prompt a generous sympathy.

"With our warmest wishes for your Royal Highness's welfare and happiness, and with renewed assurances of our devotion to our beloved Sovereign's Person and Family,—We have the honour to be, with the highest respect, your Royal Highness's most humble and most dutiful Servants,

"(Signed) James Tho. Russell, R.N., *President;* H. J. Jourdain, *Vice-President;* A. J. W. Arnott. *Treasurer;* J. C. Browne, C. Bruce, A. B. Commins, M. Connal, J. H. Finniss, Robt. Leech, George McIrvine, *Council;* C. Meldrum, *Secretary.*"

His Royal Highness replied in the following terms:—

"*To the President and Council of the Meteorological Society.*

"Gentlemen,

"I beg to thank you most heartily for your cordial welcome. It will afford me sincere pleasure to lay before Her Majesty the assurance of loyalty and devotion conveyed in your address.

"As an officer in the navy, I fully appreciate the advantageous position of this island for meteorological and magnetical observation, and it is with great satisfaction that I proceed to comply with your invitation of laying the foundation stone of a building to be specially devoted to objects of such importance.

"Your expressions of affectionate interest in all that concerns my future welfare and usefulness in the career which, by God's will, may be before me, are such as to demand a no less cordial response on my part.

"May this ceremony be auspicious to all concerned, and I sincerely trust that the Observatory, when completed, may realise all the expectations of its promoters, and continue throughout the future, not only a source of utility to the colony itself, but an aid to the cause of science, and a blessing to navigators throughout the world.

"(Signed) ALFRED."

The ceremony of laying the foundation stone was then proceeded with. His Royal Highness first deposited in a recess in the lower stone a bottle containing coins of the realm, a copy of the address, newspapers of the colony, and a paper on which was engrossed the following inscription:—

"This foundation stone of the Mauritius New Observatory was laid by Captain H.R.H. the Duke of Edinburgh, in presence of H. E. Sir Henry Barkly, K.C.B., F.R.S., Governor and Commander-in-Chief of Mauritius, at the request of the Meteorological Society, on Monday, the 30th of May, 1870."

His Royal Highness then spread the lower stone with mortar, and the upper stone was lowered into its bed. The Prince afterwards tried the stone with plumb-rule, level, and gavel in right masonic style, and declared it well and truly laid.

The trowel used by his Royal Highness, and presented to him by the society, was of solid silver, elegantly chased and of beautiful form. It was manufactured by Mr. G. Lewison, of Royal Street, and had engraved on it the following inscription:—

"Presented to His Royal Highness Alfred Ernest Albert, Duke of Edinburgh, K.G., K.T., G.C.S.I., R.N., by the Meteorological Society of Mauritius, at the laying of the Foundation Stone of a new Meteorological and Magnetical Observatory. Mauritius, 30th May, 1870."

The Secretary, Mr. Meldrum, then addressed his Royal Highness as follows:—

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* Professor Huxley examined portions of the pellicle as soon as they were removed. He at once admitted the general resemblance as regards microscopical characters between this and the pellicle which forms on solutions containing organic matter. The particles were, however, mostly indefinite in shape rather than definite, though they were obviously imbedded in a clear jelly-like material. They became deeply tinted, also, when tested with a weak magenta solution, in the same way that the monads and bacteria of an ordinary pellicle are tinted by such a fluid, whilst the jelly-like material only assumed the faintest tinge of colour.

† These were the two specimens which were mounted in Prof. Huxley's presence, and which were examined by him. After he left I spent more than two hours in thoroughly searching over these specimens with a $\frac{1}{12}''$ objective. And the result was that five fungus-spores were found in the two specimens as above stated. These are still in my possession.